Latest Benchmark Results

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Services we provide

- Guide to Software: "Decision Tree"
  - http://plato.asu.edu/guide.html
- Software Archive
- Software Evaluation: "Benchmarks"
- Archive of Testproblems
- Web-based Solvers (1/3 of NEOS)
We maintain the following NEOS solvers in 9 categories

Combinatorial Optimization  * CONCORDE [TSP Input]
Global Optimization  * ICOS [AMPL Input]
  * scip [AMPL Input][LP Input][MPS Input][OSIL Input][ZIMPL Input]
Linear Programming
  * bpmpd [AMPL Input][LP Input][MPS Input][QPS Input]
  * SoPlex80bit [LP Input][MPS Input]
Mixed Integer Linear Programming
  * feaspump [AMPL Input][LP Input][MPS Input]
  * proxy [LP Input][MPS Input]
  * qsopt_ex [AMPL Input][LP Input][MPS Input]
  * scip [AMPL Input][LP Input][MPS Input] [ZIMPL Input][OSIL Input]
Nondifferentiable Optimization  * condor [AMPL Input]
Semi-infinite Optimization  * nsips [AMPL Input]
Mixed Integer Nonlinearly Constrained Optimization
* scip [AMPL Input][LP Input][MPS Input][OSIL Input][ZIMPL Input]

Semidefinite (and SOCP) Programming (also discrete)
* csdp [MATLAB_BINARY Input][SPARSE_SDPA Input]
* mosek [MATLAB_BINARY Input][SPARSE_SDPA Input]
* penbmi [MATLAB Input][MATLAB_BINARY Input][YALMIP Input]
* pensdp [MATLAB_BINARY Input][SPARSE_SDPA Input]
* scipsdp [SPARSE_SDPA Input]
* sdpa [MATLAB_BINARY Input][SPARSE_SDPA Input]
* sdplr [MATLAB_BINARY Input][SDPLR Input][SPARSE_SDPA Input]
* sdpt3 [MATLAB_BINARY Input][SPARSE_SDPA Input]
* sedumi [MATLAB_BINARY Input][SPARSE_SDPA Input]

Stochastic Linear Programming
* bnbs [SMPS Input]
* DDSIP [LP Input][MPS Input]
* SD [SMPS Input]
### Usage of our NEOS solvers within last twelve months

<table>
<thead>
<tr>
<th>Solver</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concorde</td>
<td>30,000</td>
</tr>
<tr>
<td>SCIP</td>
<td>14,000</td>
</tr>
<tr>
<td>BPMPD</td>
<td>3,500</td>
</tr>
<tr>
<td>PENBMI</td>
<td>2,300</td>
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<tr>
<td>QSOPT_ex</td>
<td>1,400</td>
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<tr>
<td>SCIP_SDP</td>
<td>1,100</td>
</tr>
<tr>
<td>CSDP, SDPA, SD, SDPLR</td>
<td>1,000</td>
</tr>
<tr>
<td>others below</td>
<td>1,000</td>
</tr>
</tbody>
</table>
Overview of Talk

• Current and Selected Benchmarks

  – Benchmarks of Continuous Optimization Software
    * Simplex/Barrier LP/QP/SOCP, SDP, NLP, MPEC
  – Benchmarks of Discrete Optimization Software
    * MILP, MIQP, MIQCP, MISOC, MINLP

• Observations and Conclusions
COMBINATORIAL OPTIMIZATION

Concorde-TSP with different LP solvers (12-20-2017)

LINEAR PROGRAMMING

* Benchmark of Simplex LP solvers (10-17-2018)
* Benchmark of commercial LP solvers (10-17-2018)
Parallel Barrier Solvers on Large LP/QP problems (10-17-2018)
Large Network-LP Benchmark (commercial vs free) (10-17-2018)

SEMIDEFINITE/SQL PROGRAMMING

SQL problems from the 7th DIMACS Challenge (8-8-2002)
Several SDP codes on sparse and other SDP problems (10-25-2018)
Infeasible SDP Benchmark (5-9-2018)
* Large SOCP Benchmark (10-17-2018)
* MISOCP Benchmark (10-17-2018)

PROBLEMS WITH EQUILIBRIUM CONSTRAINTS

MPEC Benchmark (4-17-2018)
MIXED INTEGER LINEAR PROGRAMMING

* MILP Benchmark - MIPLIB2010 (10-21-2018)
* MILP Benchmark - MIPLIB2017 (11-1-2018)
* MILP cases that are slightly pathological (10-30-2018)
Feasibility Benchmark (11-1-2018) (MIPLIB2017)

NONLINEAR PROGRAMMING

* AMPL-NLP Benchmark (10-30-2018)

MIXED INTEGER QPs and QCPs

Non-commercial convex QP Benchmark (8-17-2018)
* Binary QPLIB Benchmark (10-30-2018)
* QPLIB-QCQP Benchmark (7-27-2018)
* Convex Discrete QPLIB Benchmark (10-30-2018)

MIXED INTEGER NONLINEAR PROGRAMMING

MINLP Benchmark (6-14-2018)
Important features of all our benchmarks

- NO PERFORMANCE PROFILES! (unreliable, TOMS 43)
- Statistics of problems (dimensions etc)
- Links to codes, problems and logfiles given
- Same selection for commercial/free codes
- many benchmark talks on personal webpage to TRACK PERFORMANCE OVER TIME
Reasons for updates

- New versions of commercial software
  - GUROBI-8.1, XPRESS-8.5.1, SAS-OR-14.6 (soon)
  - KNITRO-11.1, MOSEK-8.1
  - MATLAB-2018b (linprog, intlinprog, fmincon)
  - GAMS-25.1 (for MINLP)

- New versions of free software
  - MIPCL, SCIP, IPOPT, GALAHAD-CQP
Overview of Talk

- Current and Selected Benchmarks
  - Benchmarks of Continuous Optimization Software
    * Simplex/Barrier LP/QP, SOCP, SDP, NLP, MPEC
  - Benchmarks of Discrete Optimization Software
    * MILP, MIQP, MIQCP, MISOC, MINLP

- Observations and Conclusions
Benchmark of Simplex LP solvers

H. Mittelmann (mittelmann@asu.edu)

This benchmark was run on a Linux-PC (i7-4790K, 4.0GHz, 32GB).

CPLEX-12.8.0 CPLEX
GUROBI-8.1.0 www.gurobi.com/
MOSEK-8.1.0.63 www.mosek.com
XPRESS-8.5.1 XPRESS (1/8 threads)
CLP-1.16.11 projects.coin-or.org/Clp (with openblas)
Google-GLOP LP with Glop
SOPLEX-4.0.0 soplex.zib.de/
LP_SOLVE-5.5.2 lpsolve.sourceforge.net/
GLPK-4.64 www.gnu.org/software/glpk/glpk.html
MATLAB-R2018a mathworks.com (dual-simplex)
SAS-OR-14.3 SAS optimization

Unscaled and scaled shifted (by 10 sec) geometric mean of runtimes

<table>
<thead>
<tr>
<th></th>
<th>CPXS</th>
<th>GRBS</th>
<th>MSKS</th>
<th>XPRS</th>
<th>CLP</th>
<th>GLOP</th>
<th>SOPLX</th>
<th>LPSLV</th>
<th>GLPK</th>
<th>MATL</th>
<th>SAS</th>
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</thead>
<tbody>
<tr>
<td>Unscaled</td>
<td>49.3</td>
<td>22.8</td>
<td>142</td>
<td>26.2</td>
<td>50.0</td>
<td>292</td>
<td>461</td>
<td>5068</td>
<td>1180</td>
<td>298</td>
<td>147</td>
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<tr>
<td>Scaled</td>
<td>2.16</td>
<td>1</td>
<td>6.21</td>
<td>1.15</td>
<td>2.19</td>
<td>12.8</td>
<td>20.2</td>
<td>222</td>
<td>52</td>
<td>13.1</td>
<td>6.43</td>
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<tr>
<td>solved</td>
<td>40</td>
<td>40</td>
<td>39</td>
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<td>36</td>
<td>36</td>
<td>23</td>
<td>31</td>
<td>32</td>
<td>38</td>
<td></td>
</tr>
</tbody>
</table>

40 probs CPXS GRBS MSKS XPRS CLP GLOP SOPLX LPSLV GLPK MATL SAS
This benchmark was run on a Linux-PC (i7-4790K, 4GHz, 32GB).

The barrier\text{(B)} and deterministic automatic/concurrent\text{(C)} methods were tested of:

- CPLEX-12.8.0 CPLEX
- GUROBI-8.1.0 www.gurobi.com/
- MOSEK-8.1.0.63 www.mosek.com
- XPRESS-8.5.1 XPRESS
- MATLAB-R2018a mathworks.com (interior-point, NO CROSSOVER!)
- SAS-OR-14.3 SAS

 Unscaled and scaled shifted (by 10 sec) geometric mean of runtimes

\[
\begin{array}{cccccccccc}
28.8 & 15.0 & 49.7 & 16.3 & 47.7 & 15.9 & 22.5 & 179 & 174 \\
46 probs & 1.92 & 1 & 3.31 & 1.08 & 3.18 & 1.06 & 1.50 & 11.9 & 11.6 \\
46 solved & 46 & 46 & 44 & 46 & 46 & 46 & 46 & 42 & 41 \\
\end{array}
\]
IPOPT-3.12.11  projects.coin-or.org/Ipopt (MA97, also MA86 results, 4 threads)
KNITRO-11.1    www.artelys.com/knitro/
LOQO-7.03      www.princeton.edu/~rvdb/
PENNON-0.9     www.penopt.de/pennlp.html
SNOPT-7.7      www.scicomp.ucsd.edu/~peg/
CONOPT-3.17A   www.conopt.com/
WORHP-1.11(hyb) www.worhp.de/
XPRESS-8.5.1(Nonlinear)  www.fico.com
FMINCON-2016a  www.mathworks.com

For AMPL models see plato.asu.edu/ftp/ampl-nlp-source

The codes were run in default mode, except as indicated and with a CPU time limit of 2hrs on a 16GB, 3.4GHz Intel i7-2600. Means for table instances only.

Partial listing (123 instances; logfiles are complete)
=================================================================================
scaled shifted geom mean  6.1 1 34.9 29.1 48.3 56.0 7.82 1.60 24.5
src  problem  IPOPT KNIT LOQO PENN SNOPT CONOPT WORHP XPRESS FMINCON
=================================================================================
17 Oct 2018

Large Second Order Cone Benchmark

Hans D. Mittelmann (mittelmann@asu.edu)

Logfiles for these runs are at: plato.la.asu.edu/ftp/socp_logs/

MOSEK-8.1.0.58 MOSEK
CPLEX-12.8.0 CPLEX
GUROBI-8.1.0 GUROBI
XPRESS-8.5.1 XPRESS

These codes were tested on a selection of the SOCP problems from CBLIB2014.
The codes were run in default mode on an Intel i7-4790K (4.0 GHz, 32GB). Time limit 1 hr.

<table>
<thead>
<tr>
<th>problem solved of 18</th>
<th>CPLEX</th>
<th>GUROBI</th>
<th>MOSEK</th>
<th>XPRESS</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>18</td>
<td>18</td>
<td>18</td>
<td>18</td>
</tr>
</tbody>
</table>

3.17  1  1.14  1.34
Overview of Talk

- Current Benchmarks
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  - Benchmarks of Discrete Optimization Software
    * MILP, MIQP, MIQCP, MISOCP, MINLP

- Observations and Conclusions
Mixed-integer SOCP Benchmark

Hans D. Mittelmann (mittelmann@asu.edu)

Logfiles for these runs are at: plato.la.asu.edu/ftp/misocp_logs/

MOSEK-8.1.0.58 MOSEK
CPLEX-12.8.0 CPLEX
GUROBI-8.1.0 GUROBI
XPRESS-8.5.1 XPRESS
SCIP-6.0.0 SCIP

These codes were tested on a selection of the MISOCP problems from CBLIB2014 and from here. The codes were run in default mode (except mipgap=0) on an Intel i7-4790K (4.0 GHz, 32GB). Time limit 2 hrs.

Scaled shifted geometric means of runtimes (t/m counted as maxtime)

<table>
<thead>
<tr>
<th></th>
<th>CPLEX</th>
<th>GUROBI</th>
<th>MOSEK</th>
<th>XPRESS</th>
<th>SCIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>solved of 47</td>
<td>37</td>
<td>46</td>
<td>32</td>
<td>45</td>
<td>31</td>
</tr>
</tbody>
</table>

4.82 1 12.4 1.67 37.6
Mixed Integer Linear Programming Benchmark (MIPLIB2010)

H. Mittelmann (mittelmann@asu.edu)

The following codes were run with a limit of 2 hours on the MIPLIB2010 benchmark set with the MIPLIB2010 scripts on two platforms.
1/4 threads: Intel i7-4790K, 4 cores, 32GB, 4GHz, available memory 24GB;
12 threads: Intel Xeon X5680, 12 cores, 32GB, 3.33Ghz, available memory 24GB

CPLEX-12.8.0: CPLEX
GUROBI-8.1.0 GUROBI
(F)SCIP/cpx/spx]-6.0.0: FiberSCIP (SCIP+CPLEX/SOPLEX on 1 thread)
CBC-2.9.8: CBC
GLKP-4.65: GLPK
LP_SOLVE-5.5.2: LPSOLVE
XPRESS-8.5.1: XPRESS
MATLAB-2018b: MATLAB (intlinprog)
MIPCL-1.6.1: MIPCL
SAS-OR-14.3: SAS

Table for single thread, Result files per solver, Log files per solver
Table for 4 threads, Result files per solver, Log files per solver
Table for 12 threads, Result files per solver, Log files per solver

Statistics of the problems can be obtained from the MIPLIB2010 webpage.
The third line lists the number of problems (86 total) solved.

<table>
<thead>
<tr>
<th>Thr</th>
<th>CBC</th>
<th>CPLEX</th>
<th>GUROBI</th>
<th>SCIPC</th>
<th>SCIPS</th>
<th>XPRESS</th>
<th>MATLAB</th>
<th>SAS</th>
<th>MIPCL</th>
<th>GLPK</th>
<th>LP_SOL</th>
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<tr>
<td>unscal</td>
<td>1639</td>
<td>72.2</td>
<td>41.6</td>
<td>239</td>
<td>330</td>
<td>83.1</td>
<td>3002</td>
<td>121</td>
<td>453</td>
<td>6925</td>
<td>5616</td>
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<tr>
<td>scaled</td>
<td>39</td>
<td>1.74</td>
<td>1</td>
<td>5.75</td>
<td>7.94</td>
<td>2.00</td>
<td>72.2</td>
<td>2.90</td>
<td>10.9</td>
<td>167</td>
<td>135</td>
</tr>
<tr>
<td>solved</td>
<td>53</td>
<td>87</td>
<td>87</td>
<td>83</td>
<td>76</td>
<td>86</td>
<td>32</td>
<td>84</td>
<td>76</td>
<td>2</td>
<td>7</td>
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</table>

<table>
<thead>
<tr>
<th>Thr</th>
<th>CBC</th>
<th>CPLEX</th>
<th>FSCIPC</th>
<th>FSCIPS</th>
<th>GUROBI</th>
<th>XPRESS</th>
<th>MIPCL</th>
<th>SAS</th>
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<tbody>
<tr>
<td>unscal</td>
<td>843</td>
<td>36.4</td>
<td>240</td>
<td>294</td>
<td>24.2</td>
<td>40.3</td>
<td>177</td>
<td>72.6</td>
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<tr>
<td>scaled</td>
<td>34.8</td>
<td>1.50</td>
<td>9.90</td>
<td>12.1</td>
<td>1</td>
<td>1.66</td>
<td>7.29</td>
<td>3.00</td>
</tr>
<tr>
<td>solved</td>
<td>66</td>
<td>86</td>
<td>80</td>
<td>79</td>
<td>87</td>
<td>87</td>
<td>84</td>
<td>85</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Thr</th>
<th>CBC</th>
<th>CPLEX</th>
<th>FSCIPC</th>
<th>FSCIPS</th>
<th>GUROBI</th>
<th>XPRESS</th>
<th>MIPCL</th>
<th>SAS</th>
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<tbody>
<tr>
<td>unscal</td>
<td>668</td>
<td>37.5</td>
<td>247</td>
<td>328</td>
<td>25.2</td>
<td>39.5</td>
<td>165</td>
<td>85.4</td>
</tr>
<tr>
<td>scaled</td>
<td>27</td>
<td>1.49</td>
<td>9.80</td>
<td>13.0</td>
<td>1</td>
<td>1.57</td>
<td>6.53</td>
<td>3.39</td>
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<tr>
<td>solved</td>
<td>69</td>
<td>87</td>
<td>78</td>
<td>76</td>
<td>87</td>
<td>87</td>
<td>82</td>
<td>82</td>
</tr>
</tbody>
</table>
The following codes were run on the benchmark instances of the forthcoming MIPLIB2017 on an Intel Xeon X5680 (32GB, Linux, 64 bits, 2*6 cores) and with 48 threads on an Intel Xeon E5-4657L, 48 cores, 512GB, 2.40GHz (available memory 256GB). 2/1 hours max. More codes to be added later.

**CPLEX-12.8.0, GUROBI-8.1.0, XPRESS-8.5.1**

<table>
<thead>
<tr>
<th>no. of probs</th>
<th>CPLEX</th>
<th>GUROBI</th>
<th>XPRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 threads</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>240</td>
<td>307</td>
<td>207</td>
<td>416</td>
</tr>
<tr>
<td>solved</td>
<td>1.48</td>
<td>1</td>
<td>2.01</td>
</tr>
<tr>
<td></td>
<td>195</td>
<td>212</td>
<td>180</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>no. of probs</th>
<th>CPLEX</th>
<th>GUROBI</th>
<th>XPRESS</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 threads</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>240</td>
<td>238</td>
<td>176</td>
<td>336</td>
</tr>
<tr>
<td>solved</td>
<td>1.35</td>
<td>1</td>
<td>1.90</td>
</tr>
<tr>
<td></td>
<td>199</td>
<td>211</td>
<td>180</td>
</tr>
</tbody>
</table>
The above solvers were run on a 3 GHz Intel i7-5960X (8 cores, 48GB) on the binary nonconvex problems (128 total) from QPLIB. Times given are elapsed times in seconds. Mipgap is zero, time limit 1hr; 8 threads, except SCIP. Only those instances are shown for which at least one solver succeeded. Shifted and scaled geometric mean of runtimes:

| mean | 2.89 | 1 | 18.5 | 40.2 | 44.5 | 1.82 | 30.8 |
| solved | 71 | 80 | 27 | 19 | 11 | 75 | 23 |

<table>
<thead>
<tr>
<th>prob#</th>
<th>CPLEX</th>
<th>GUROBI</th>
<th>BARON</th>
<th>SCIP</th>
<th>ANTIGONE</th>
<th>XPRESS</th>
<th>FSCIP</th>
</tr>
</thead>
</table>

Logfiles at plato.asu.edu/ftp/qplib_logs/
QPLIB-QCQP Benchmark

H. Mittelmann (mittelmann@asu.edu)

Logiles at plato.asu.edu/ftp/qcqp_logs/

Baron-18.5.8  BARON
ANTIGONE-1.1  ANTIGONE
SCIP-6.0.0    SCIP/CPLEX
COUENNE-0.5   COUENNE
CPLEX-12.8.0  CPLEX

The above solvers were run on a 3 GHz Intel i7-5960X (8 cores, 48GB) on the (nonconvex) QCQPs (37 total) with quadratic objective and the continuous QCQPs (52 total) with linear objective as well as the nonbinary QPs (19 total) from QPLIB. Times given are elapsed times in seconds. Mipgap is zero, time limit 3hrs. Only those instances are shown for which at least one solver succeeded. Shifted and scaled geometric mean of runtimes:

mean   2.36   1   2.28   4.54
solved 19   29   17    9

<table>
<thead>
<tr>
<th>prob#</th>
<th>BARON</th>
<th>ANTIGONE</th>
<th>SCIP</th>
<th>COUENNE</th>
</tr>
</thead>
</table>

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### QPLIB-QCQP Benchmark

**H.Mittelmann (mittelmann@asu.edu)**

(continued, nonbinary QPs)

<table>
<thead>
<tr>
<th>prob#</th>
<th>BARON</th>
<th>ANTIGONE</th>
<th>SCIP</th>
<th>COUENNE</th>
<th>CPLEX</th>
</tr>
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<td>0018</td>
<td>t</td>
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<td>t</td>
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<td>0031</td>
<td>3526</td>
<td>t</td>
<td>t</td>
<td>t</td>
<td>2666</td>
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<tr>
<td>0343</td>
<td>t</td>
<td>7682</td>
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<td>t</td>
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<td>2702</td>
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Logiles at plato.asu.edu/ftp/convex_logs/

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<td>Bonminh-1.8</td>
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The above solvers were run on a 3 GHz Intel i7-5960X (8 cores, 48GB) on the 31 discrete convex problems from QPLIB. Times given are elapsed times in seconds. Mipgap zero, time limit 2hrs, 8 threads; SCIP 1 thread

Shifted and scaled geometric mean of runtimes:

| mean | 2.90 | 1 | 8.18 | 3.07 | 11.6 | 9.24 | 12.8 | 10.8 | 13.4 |
| solved | 20 | 22 | 11 | 14 | 9 | 14 | 12 | 9 | 11 |

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Overview of Talk

• Current Benchmarks
  – Benchmarks of Continuous Optimization Software
    * Simplex/Barrier LP/QP, SDP, NLP, MPEC
  – Benchmarks of Discrete Optimization Software
    * MILP, MIQP, MIQCP, MISOC, MINLP

• Observations and Conclusions
Commercial Solver Strengths

ANTIGONE nonconvex MIQCP
BARON nonconvex MINLP
CPLEX MILP, nonconvex MIQP
Gurobi LP/Simplex, LP/Barrier, SOCP, MILP, convex MIQCP
KNITRO NLP
XPRESS LP/Simplex, LP/Barrier, MISOC, binary QP,
MOSEK SDP, SOCP

Noncommercial Solver Strengths

BONMIN convex MIQCP
BPMPD QP
CSDP, SDPT3 SDP
CLP LP/Simplex
IPOPT NLP
SCIP convex MIQCP, nonconvex MINLP
coming soon:

more MIPLIB2017, QPLIB, MINLP etc

slides at: http://plato.asu.edu/talks/

Thank you!